consisting of optically anisotropic molecules, ferroelectric materials exhibiting optical birefringence, and materials exhibiting Faraday-activity.

A6 Cond'd

67. (First Amendment) The method according to claim 66 wherein said optically anisotropic molecules are selected from the group consisting of nematic liquid crystals and chiral molecules including cholesteric liquid crystals.

68. (First Amendment) The method according to claim 67 wherein said optically anisotropic molecules is a nematic liquid crystal, and wherein said band structure is modulated either globally or locally by rotations of a nematic director field of the nematic liquid crystal by application of an external electric field globally to the entire photonic crystal or locally to preselected portions of said photonic crystal.

REMARKS

Amendments to the Specification

The description in the Summary of Invention has been amended to conform the Summary to be commensurate with amended claims 1, 38 and 62 discussed hereinafter.

The claims have been amended to more clearly and succinctly claim the present invention. Claims 1, 38 and 62 have been amended to recite "for providing control of propagation of light through said photonic crystal." The whole thrust of the present invention is to provide photonic crystals which have photonic band structures which can

be tuned in a controlled way for controlling light propagation **through** the photonic crystals. This feature is clearly the intent of the description of the invention. One example (of many) of how this control of light propagation is achieved by tuning the band structure is found on page 18, lines 29 to line 9 on page 19, particularly the last sentences from lines 7 to 9 on page 19 where it is disclosed:

"This illustrates the use of the infiltrated inverse opal material as a tunable filter which can selectively pass or stop light over a significant bandwidth. "

Another example of how the tunable band structure can be used to control emission properties of light from photonic crystal is on page 19, from lines 23 to line 5 of page 20. Figures 13 to 15 also show the characteristics and control by the modulated photonic band structure of light waves passing through the photonic crystals. Therefore, Applicants submit this amendment is fully supported by the disclosure.

Claims 66-68 have been objected to for the informality pointed out by the Examiner in respect of the preamble. Responsively claims 66-68 have been amended to delete the phrase "The photonic crystal according to" and insert the phrase --The method according to --.

The Examiner has rejected claims 39-51, 53-61, 64 and 69 under 35 U.S.C. 112, first paragraph for lack of enablement so that a person skilled in the art would not be able to make the invention commensurate with these claims. Applicants respectfully request the Examiner to reconsider and withdraw this rejection in view of the following.

First, in the description on page 26, lines 6 to 13 discuss different embodiments, where it is taught

"***The photonic crystal dielectric composite may consist of a tunable backbone, with high refractive index, and a periodic array of void regions of air e.g. overlapping air spheres in the fcc inverted opal structure.*** *Alternatively, the photonic crystal may consist of a non-tunable backbone and one or more tunable (optically anisotropic) materials which either fill or partially fill the air pores.* ***It may also consist of a tunable backbone, with high refractive index, and, instead of air voids, another dielectric solid having sufficiently low refractive index so that the composite dielectric material has a photonic band structure.***"

Example 4 teaches how the backbone may be made tunable using Faraday-activity in for example silicon which has had magnetic ions embedded therein. In this case the first dielectric constituent (silicon exhibiting Faraday-activity) and its refractive index properties may be modulated as shown in Figures 16 and 17. This is described on page 22, lines 24 to page 23, lines 23.

Further, the first dielectric component can be chosen from one of the optically anisotropic ferro-electrics which clearly have a higher refractive index than a liquid crystal. This could be tuned by the application of an electric field. If the anisotropic ferro-electric has voids which are partially filled with liquid crystal, then the liquid crystal can also be tuned either by applying a field or by changing the temperature. Hence these claims are enabled through selection of combinations of materials from the Examples listed.

In view of the above, Applicants respectfully submit claims 39-51, 53-61, 64 and 69 are enabled by the specification as a whole so that those skilled in the art could work

the invention of these claims. Withdrawal of this rejection is therefore requested.

Patentability Of the Claims Over The Cited References

The Examiner has rejected claims 1, 2, 4-5, 7-8, 11, 38, 52 and 62 under 35 U.S.C. 102(b) as being anticipated by United States Patent No. 6,052,213 issued to Burt et al. (Burt). The Examiner is requested to reconsider and withdraw this rejection in view of the following observations on the difference between the claims of the present invention and the disclosure of Burt et. al.

Burt is directed to a providing an optical diffraction grating as disclosed in the Abstract, and lines 41-46 of column 1 and lines 54 to 57. It is noted that each of the independent claims of Burt recites "An optical diffraction grating". While the present claims make use of similar terminology to those of Burt, they do not overlap in substance with the teachings of Burt. Burt make use of the terminology "photonic crystal" (PC) and "photonic band gap" (PBG), to distinguish their invention from the mechanisms for optical wave guidance that arise from a PBG. The essential property of a PC, namely of exhibiting a well defined "photonic band structure" (which is further punctured by the occurrence of the complete PBG) is irrelevant to the invention of Burt and the mechanism whereby their device operates. Just below the section in column 1 cited by the Examiner in the patent to Burt. Burt states that "Most work on photonic crystals has focused on producing these photonic band gaps. However, a novel analysis by the present inventor has shown that the photonic crystals exhibit another property which can be exploited to provide a highly efficient grating" (see Burt line 64, column 1 to line 1, column 2). The invention of Burt is, therefore, distinct from

Applicants' invention.

Applicants' invention not only focuses on creating a PBG, but also tuning this PBG "**for providing control of propagation of light through said photonic crystal**" as recited in amended claims 1 and 62. Starting from claim 1 of the present application, the Applicants clearly distinguish their PC as one which has a well defined "photonic band structure". All subsequent claims (2, 4-5, 7-8, and 26) carry the same distinction.

Applicants note that the use of the terminology "photonic crystal" disclosed in Burt is an exaggeration and not correct. The preferred embodiment of the invention of Burt consists of only a few or even just one row of holes (see line 15-24, column 2 of Burt). A photonic crystal is generally regarded as a material with a very large number of repeating units in all directions, within which a beam of light can propagate. More particularly, in Figures 1 and 2 of Burt, it is clear that their invention consists of a small "diffraction grating" rather than a "photonic crystal". As the size of such a diffraction grating becomes larger and larger, the "photonic crystal" label may also be applied. However, Burt only makes use of the reflection property of this large grating, rather than propagation of light within the PC and mediated by its "photonic band structure". The invention of Burt simply makes use of the fact that the angle of reflection from the surface of the grating can be changed by varying the refractive index of the grating. Likewise, in the case of light that is coupled to and from the "diffraction grating" by waveguides (see line 30-42, column 2 of Burt), there is only a single scattering from the grating rather than propagation within a bulk photonic crystal.

In Applicants' novel analysis, they demonstrate **that propagation of light *within***

the PC can be altered and controlled by controlled changing of the refractive index. This occurs through the addition or removal of propagating modes within the PC over specific frequency intervals. ***Such control over light propagation within a photonic crystal simply cannot be achieved using the teachings disclosed in Burt***. In other words Burt neither discloses, nor could it be derived by a "person skilled in the art" upon reading Burt the subject matter of claims 1 and 2 which relate to contolling light propagation INSIDE a BULK tunable photonic crystal as claimed in their application. There is a clear difference between Bloch wave propagation inside a photonic crystal or PBG material and reflection or transmission from small gratings composed of spherical particles.

Therefore, Applicants respectfully submit that the concepts underlying the invention of Burt and their invention are almost mutually exclusive. Likewise the applications of these distinct concepts in actual devices is almost mutually exclusive. In Applicants' invention, defects (waveguides) are placed within the photonic crystal to guide light. If these defects have a tunable refractive index, the propagation of light within the PC can be switched (see Example 6 of the present invention). No consideration of defects within the PC is described by Burt.

In view of the foregoing, Applicants submit that the subject matter of claims 1 and 62 are not disclosed in Burt and those skilled in the art reading Burt would not be led to the invention as recited in these claims. Withdrawal of these 102(b) rejections is therefore respecfully requested of claims 1, 38 and 62 and the respective claims depending therefrom are requested.

Regarding the rejection of claims 38 and 52, as mentioned above with respect to claims 1, 2, and 62, Applicants strenuously disagree with the Examiner for attributing to Burt the mechanism of a "tunable photonic band structure" and a complete "photonic band gap". While Burt has disclosed that liquid crystals and various tunable semiconductor materials may give rise to tunability in the reflection of light from a "diffraction grating", this is quite distinct from Applicants' invention which relies on the tunabilty of the photonic band structure resulting in control over the properties of light propagating therein, for example by the addition and removal of entire spectral ranges within a photonic crystal in which light propagates. Therefore Applicants respectfully request the Examiner to withdraw this rejection.

The Examiner has rejected claims 3,6,9,10, 12-20, 36, 63, 66, and 67under 35 U.S.C. 103(a) as being unpatentable over Burt as applied to claims 2 and 62 and further in view of Zakhidov et al.

In view of the comments above in respect of Burt it is submitted this reference is directed to the same invention as recited in these claims and therefore is not an appropriate reference to cite and combining it with Zakhidov still does not give the subject matter of the present invention.

The same considerations apply here as described above. As stated above, Burt's use of the terminology "photonic crystal" is not strictly corrrect as applied to his diffraction gratings made from spherical particles so as blur the distinction between the idea of "reflection from a diffraction grating" (Burt's invention) and "propagation through a bulk photonic crystal" as in the present invention.

While the invention of Zakhidov may legitimately be referred to as a "photonic crystal", it by no means exhibits a "photonic band gap". The structures of Zakhidov are simply large scale periodic structures with improved "diffraction efficiency" relative to Burt. The occurrence of a "photonic band gap" (PBG) requires far more stringent conditions than anything described by Burt or Zakhidov. Futhermore, in order to make the complete PBG tunable, very special locations and concentrations of tunable material are required (as illustrated in Applicants' invention) but both Burt and Zakhidov are completely silent with respect to teaching how to tune the photonic band structure of a photonic crystal. Therefore Applicants submit the combination of Burt and Zakhidov does not give the subject matter of any of Applicants' claims.

In view of the foregoing it is respectfully submitted the present application recites subject matter which is patentably distinguishable over the cited references and allowance of the application is courteously solicited.

Should the Examiner have any questions regarding the amendments made herein, it would be appreciated if the Examiner would contact the undersigned attorney of record at the telephone number shown below for purposes of expediting the prosecution of this application. **Please send all correspondence to the address below.**

Respectfully submitted,

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MARKED UP VERSION SHOWING THE AMENDMENTS

(In The Description)

On page 4 delete the paragraphs from lines 24 to page 5, line 20 and insert the following paragraphs:

" Therefore, in one aspect of the invention there is provided a photonic crystal having a tunable photonic band structure, comprising;

a periodic composite dielectric material having at least two dielectric constituents including a first dielectric constituent having a first refractive index and a second dielectric constituent having a second refractive index smaller than the first refractive index so that the periodic composite dielectric material has a photonic band structure; and

at least of said at least two dielectric constituents having refractive index properties which can be locally or globally changed throughout said photonic crystal in

a controlled manner whereby changing the refractive index properties modulates said photonic band structure locally or globally throughout said photonic crystal for providing control of propagation of light through said photonic crystal.

In another aspect of the invention there is provided a photonic crystal having a tunable photonic band structure, comprising:

a periodic composite dielectric material having a first dielectric constituent having a first refractive index and void regions located periodically throughout a volume of said periodic composite dielectric material, a second dielectric constituent located in said void regions having a second refractive index sufficiently smaller than the first refractive index so that the periodic composite dielectric material has a photonic band structure; and

at least one of said first and second dielectric constituents being optically anisotropic and having refractive index properties which can be locally or globally modified in a controlled manner whereby changing the refractive index properties changes said photonic band structure for providing control of propagation of light through said photonic crystal. "

On page 6, delete the paragraph from lines 19 to 28, and insert the following paragraph as follows:

" In another aspect of the invention there is provided a method of tuning a photonic band structure in a photonic crystal, comprising:

<u>providing a photonic crystal having a periodic composite dielectric material including a first dielectric constituent having a first refractive index, and at least a second dielectric constituent having [an] a second refractive index constant sufficiently smaller than the first refractive index so that the periodic composite dielectric material has a photonic band structure; and</u>

<u>globally or locally changing the refractive index properties of one of said first and second dielectric constituents in a controlled manner so that said photonic band structure is changed in a controlled manner by application of one of an electric, magnetic and electromagnetic field for providing control of propagation of light through said photonic crystal</u>. "

Claim Amendments

1. (First Amendment) A photonic crystal having a tunable photonic band structure, comprising;

a periodic composite dielectric material having at least two dielectric constituents including a first dielectric constituent having a first refractive index and a second dielectric constituent having a <u>second</u> refractive index smaller than the first refractive index so that the periodic composite dielectric material has a photonic band structure; and

at least of said at least two dielectric constituents having refractive index properties which can be locally or globally changed throughout said photonic crystal in

a controlled manner whereby changing the refractive index properties modulates said photonic band structure locally or globally throughout said photonic crystal <u>for providing control of propagation of light through said photonic crystal</u>.

38. (First Amendment) A photonic crystal having a tunable photonic band structure, comprising;

a periodic composite dielectric material having a first dielectric constituent having a first refractive index and void regions located periodically throughout a volume of said periodic composite dielectric material, a second dielectric constituent located in said void regions having a second refractive index sufficiently smaller than the first refractive index so that the periodic composite dielectric material has a photonic band structure; and

at least one of said first and second dielectric constituents being optically anisotropic and having refractive index properties which can be locally or globally modified in a controlled manner whereby changing the refractive index properties changes said photonic band structure <u>for providing control of propagation of light through said photonic crystal</u>.

62. (First Amendment) A method of tuning a photonic band structure in a photonic crystal, comprising; providing a photonic crystal having a periodic composite dielectric material including a first dielectric constituent having a first refractive index, and at least a second dielectric constituent having [an] <u>a</u> second refractive index constant

sufficiently smaller than the first refractive index so that the periodic composite dielectric material has a photonic band structure; and

globally or locally changing the refractive index properties of one of said first and second dielectric constituents in a controlled manner so that said photonic band structure is changed in a controlled manner by application of one of an electric, magnetic and electromagnetic field <u>for providing control of propagation of light through said photonic crystal</u>.

66. (First Amendment) The [photonic crystal] <u>method</u> according to claim 63 wherein said optically anisotropic material infiltrated into said void regions is selected from the group consisting of optically anisotropic molecules, ferroelectric materials exhibiting optical birefringence, and materials exhibiting Faraday-activity.

67. (First Amendment) The [photonic crystal] <u>method</u> according to claim 66 wherein said optically anisotropic molecules are selected from the group consisting of nematic liquid crystals and chiral molecules including cholesteric liquid crystals.

68. (First Amendment) The [photonic crystal] <u>method</u> according to claim 67 wherein said optically anisotropic molecules is a nematic liquid crystal, and wherein said band structure is modulated either globally or locally by rotations of a nematic director field of the nematic liquid crystal by application of an external electric field globally to the entire photonic crystal or locally to preselected portions of said photonic crystal.